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LAWRENCE LIVERMORE NATIONAL LABORATORY

DHS-STEM Summary Report

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DHS-STEM Internship

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DHS-STEM Summary Report

My internship this summer was hosted at Lawrence Livermore National Laboratory in Livermore, California. My role was to perform data analysis using data and variable definitions collected by Decision Sciences International Corporation (DSIC). During my internship I had to use Livermore's Computing system, Python, and Matlab to process and deserialize data. I also had to attend weekly Department of Homeland Security (DHS) meetings that covered the following topics: biosecurity, 24/7 reach-back at the lab, radiation detection, nuclear detonation effects analysis, and response planning. The lab also offered tours of the Terascale Simulation Facility (TSF), the High Explosives Applications Facility (HEAF), and tours of the National Ignition Facility (NIF). While at the lab, I have had the opportunity to speak with employees about their performed daily tasks while working at the lab. This has helped me determine what type of pathway I want to take for graduate school, and if I would enjoy full time employment at the lab. The first week and a half of my internship was spent learning about how the Multi-Mode Passive Detection System (MMPDS) worked through reading papers involving muon tomography and reading the AP plan (draft) for the MMPDS. Two days also consisted of meetings where DSIC walked through system components and answered questions about the system.

The Multi-Mode Passive Detection System (MMPDS), created by Decision Sciences, is designed to detect special nuclear material (SNM) that is either high density/high atomic number (Z), or emits gamma radiation. The system uses drift tubes (**Figure 1**) to measure the trajectories of cosmic muons and infer the presence of a high Z material through scattering. The tubes also serve as gamma counters. The Advanced Technology Demonstration (ATD) of this system is being done by the Nuclear and Radiological Imaging Platform (NRIP) program in the DNDO-TAR directorate. The purpose of NRIP is to encourage the Research and Development (R&D) community to develop prototypes with improved methods to screen cargo trailers, cargo containers, and passenger vehicles for radiological or nuclear (R/N) threats. The prototypes represent systems to be used at land and sea ports of entry (POE), ports of departure (POD), and at check points to be used as portal monitors.

During the internship I focused on optimizing integration time of the gamma detection feature of the system. The MMPDS will alarm if a threshold for gamma counts (shift + gradient) is exceeded. The gradient was not analyzed in this study due to time constraints. A gamma ray passing through the drift tubes will produce electrons by Compton scattering within the tube walls. These electrons ionize the gas within the tubes, drift towards the anode wire in the center, and high electric fields near the anode wire cause an avalanche of electrons, creating a pulse on the anode wire, which is digitized and recorded. Gamma rays produce quasi-random drift tube hit patterns, whereas muon tracks result in localized groups of tube hits. Thus, hits due to gamma rays and muons are differentiated by different geometric patterns.

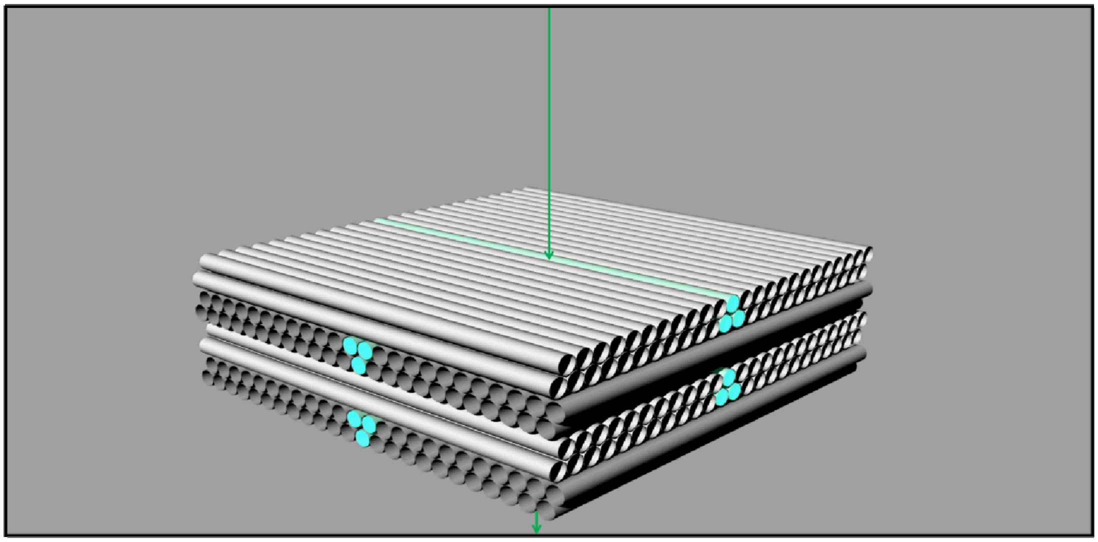

Figure 1: Muon Trajectory Through Drift Tubes

Gamma detection (resolving the shift) involves creating a histogram representing the number of tubes versus number of gamma counts per second. The gamma counts per second depend on the bin width of the histograms. The shift is the difference seen in the horizontal distance between the two histograms, overlaid onto a single graph, where one histogram is the baseline while the other histogram has a source present. The threshold of alarm should be set to minimize the amount of false alarms while maintaining source detection abilities. Longer integration times lead to increased sensitivity (lower thresholds). However, minimizing the scan time reduces costly shipping delays at ports of entry and ports of departure.

Challenges that occurred when reading in data files for analysis included incomplete data, and learning how to use Lawrence Livermore National Laboratory's (LLNL) Livermore Computing (LC) system to compile and run Google's Protoc tool to create Python code for reading MMPDS files. Python, which I had to learn, was used to decompress and deserialize data, allowing it to be further analyzed. This was a lengthy process that had several dead ends. Before settling on python, weeks were spent creating Protoc compilers for Java, Matlab, and Python, and manipulating files in an attempt to read the data contained in Protobuf files. The files supplied data definitions that were required tools for creating useful code. The histograms used to determine shifts in gamma counts were created in Python. For the purpose of sensitivity analysis, we combined data from various numbers of files representing different amounts of time. For example, the selected scan's data files would have only two data files write out information for a histogram, then four, six, eight, ten, twelve, and sixteen. The histograms were output by Python to CSV file format for further analysis in Matlab. The histogram output by Matlab is seen below in **Figure 2.** Challenges with Python included the length of run time required to read through data files. For longer scans, it would take up to two hours to read and process data. Python compiles the program as it runs, while FORTRAN, the first programming language I learned, compiles the code before it is run, resulting in significantly less run time.

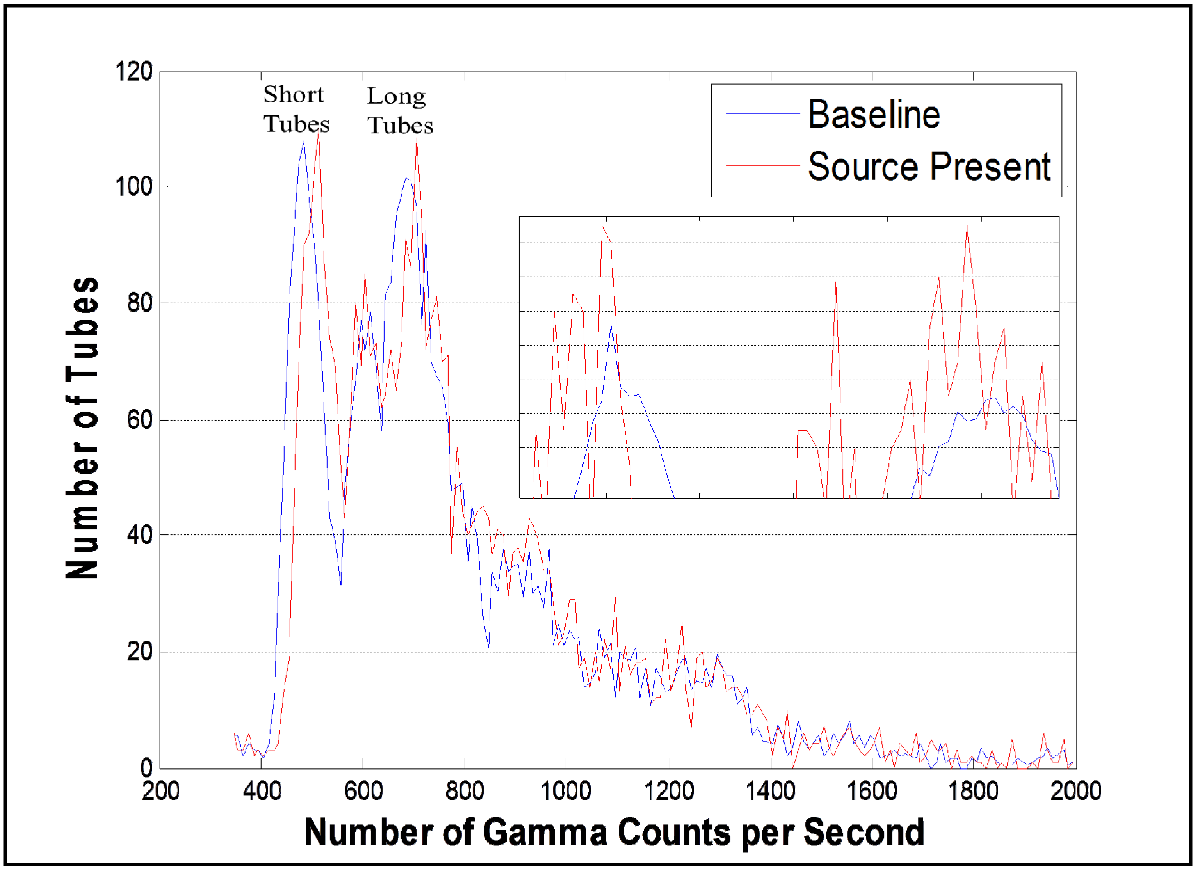

Figure 2: Number of Tubes vs. Number of Gamma Counts per Second Histogram

Matlab was used for sensitivity analysis, creating figures, and calculating gamma histogram shifts via statistical cross-correlation methods. Statistical cross-correlation refers to the correlations between two entries of two vectors. For this study, the two vectors were the baseline and the source present histogram. Parabolic interpolation of the correlation was used to obtain a peak position shift. This technique allowed us to determine the shift with finer resolution than the histogram bin width. The sensitivity calculations were then performed by plotting the standard deviations of the shifts for combinations of N=2, N=4, N=6, N=8, N=10, N=12, and N=16 files. In the absence of systematic errors, the standard deviation should decrease as $\frac{1}{\sqrt{N}}$. Instead, standard deviation decreased until N=6, then either only slightly decreased from there, or varied back and forth within a constant range of values. The file count was then converted into time, resulting in a nearly optimal scan time of 30 seconds, as seen below in **Figure 3.** DSIC has chosen an integration time of 30 seconds, which is consistent with the optimal value found in this study.

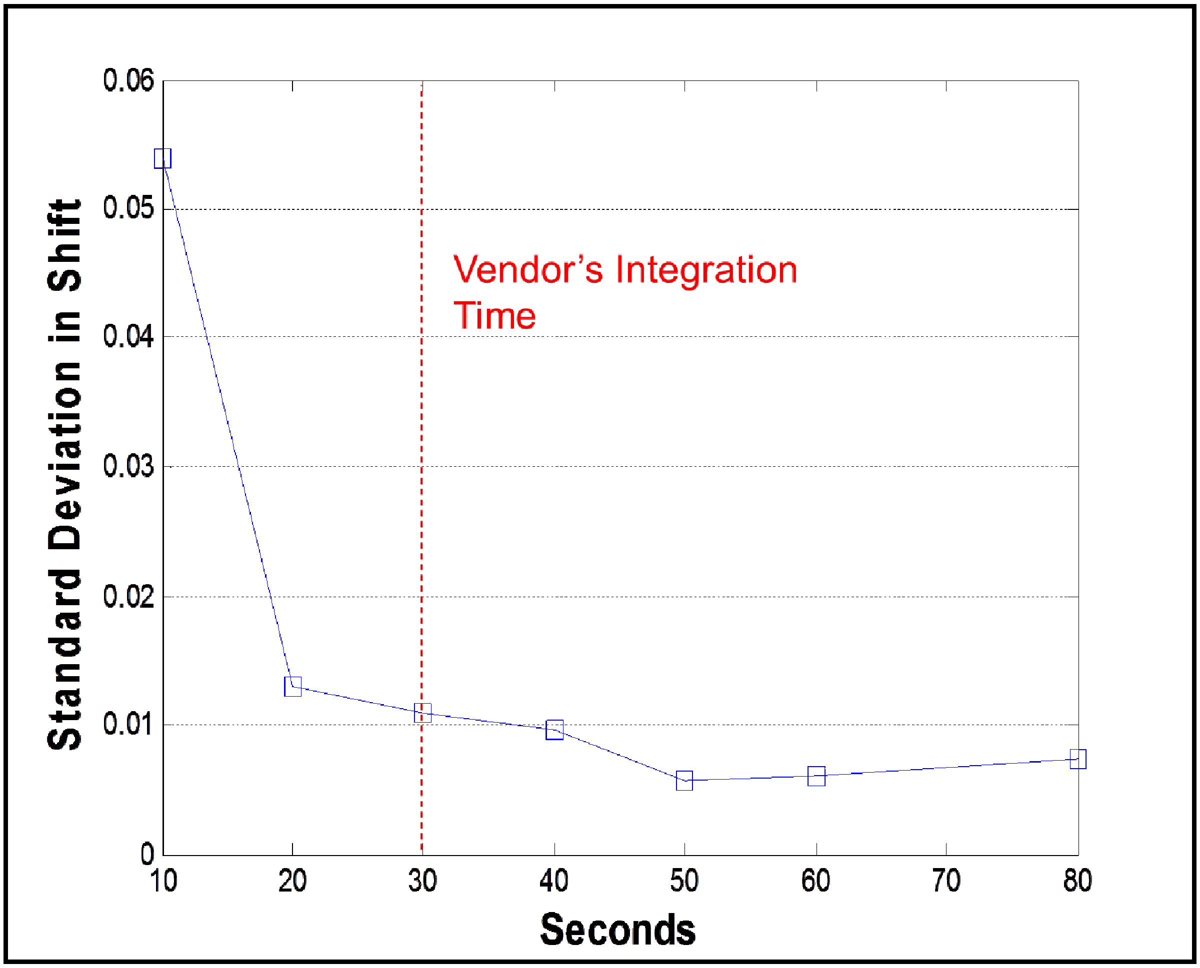

Figure 3: Optimizing Integration Time

Matlab was also used to plot gamma shifts versus time to make sure the baselines were stable over a period of minutes to hours (see **Figure 4**). Baseline 1 and Baseline 2 both appeared to be stable, as was the elevated shift with the source present.

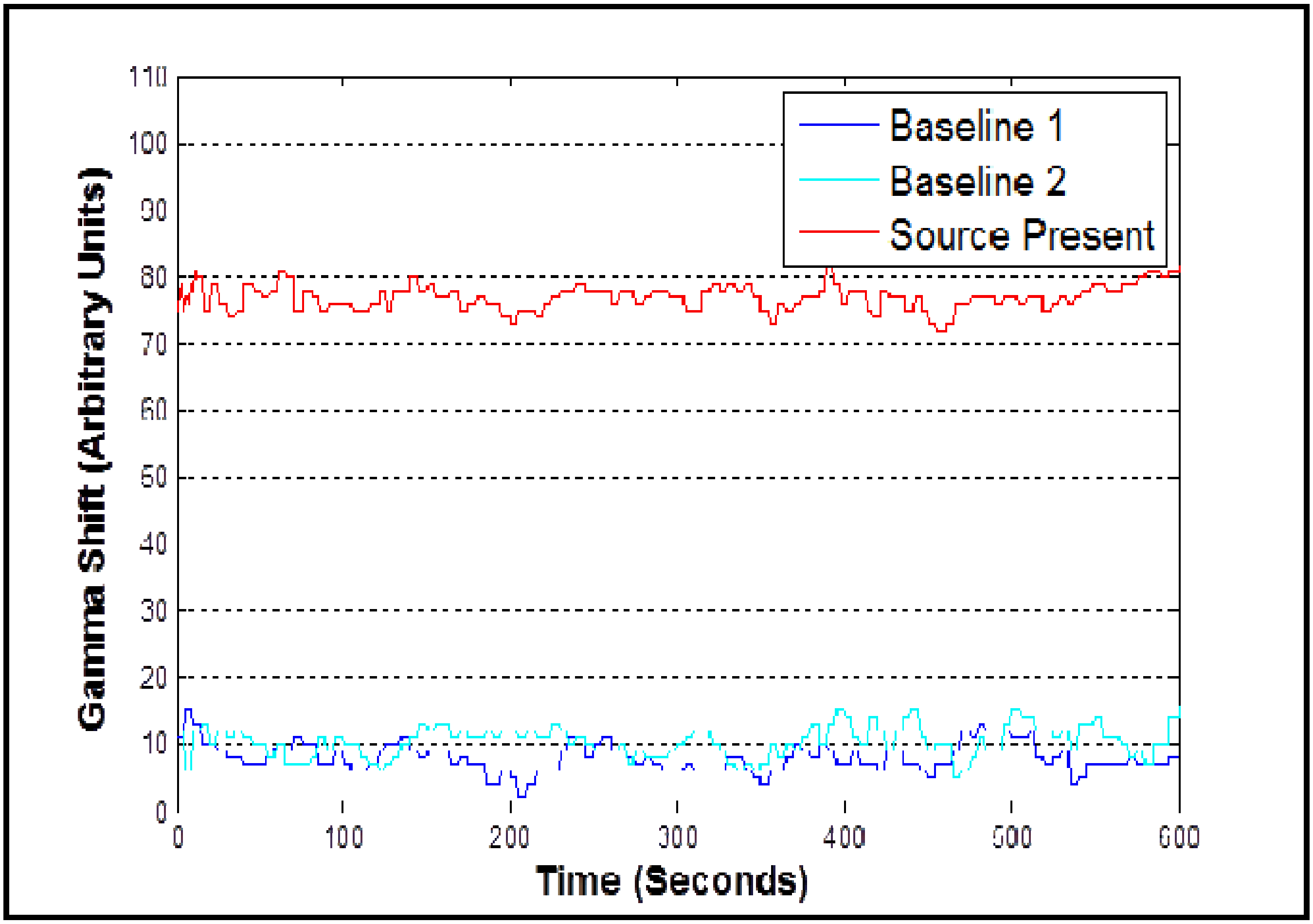

Figure 4: Stability in Gamma Shifts Over Time

During the internship I learned how to program more efficiently in Matlab, such as creating efficient scripts to walk through a file system to read large amounts of data and automatically save figures with meaningful file names. A particularly useful technique I learned was how to create file names for output that dynamically change with the selected input data file. The skills that I have learned using Matlab and Python that involve reading in massive amounts of data files are crucial, and this type of coding isn't emphasized in my university setting. Python will also become a valuable skill learned at the lab.

Programming wasn't the only knowledge I gained this summer. I have been considering a career in emergency response, but also would like to work on maintaining the nuclear stockpile. For my career pathway, the most influential DHS seminars that DHS interns are required to attend on a weekly basis covered 24/7 Reach-Back, Nuclear Detonation Effects Analysis, Response Planning, and covered emergency response programs that exist in the Weapons and Complex Integration (WCI) department at LLNL. These meetings covered responsibilities of emergency response programs including the National Nuclear Security Administration's (NNSA) Joint Technical Operations Team (JTOT), Accident Response Group (ARG), Triage, Radiological Assistance Program (RAP), and the National Atmospheric Release Advisory Center (NARAC). Lab employees within WCI have the option to work in emergency response part time while they work on their main projects at the lab. These programs involve participating in emergency response exercises and deployment if an incident such as Fukushima were to take place. It was also a great opportunity to see new scientific concepts being proven at the lab such as NIF, being able to see supercomputers on the TSF tour that are similar to those used by the LC system, and to see HEAF. At HEAF, interns learned about new weapons created that are lighter and able to deliver damage to a smaller area. With these weapons, only the target would become damaged without shrapnel damaging surrounding structures.

I have met with various scientists within WCI, who work in nuclear weapons design or nuclear weapons engineering, to inquire about daily activities performed while working in the department. This has helped determine if working with the nuclear stockpile would be of interest to me. I have also been able to find out differences in job opportunities with a master's degree versus a PhD in nuclear engineering (I am still trying to decide between the two), and if I did want to work in weapons, what concentration of nuclear engineering are they looking for in graduate students. A concentration in nuclear materials would provide me with opportunities for more hands-on, experimental work, and is most useful for maintaining the nuclear stockpile. I mostly enjoy hands-on experimental work and have been considering either nuclear materials or a radiation/nonproliferation pathway in nuclear engineering at my current university. The lab has increased my knowledge on available job opportunities involving experimental work, and what type of graduate degree I would need. I will be choosing a concentration in nuclear materials for graduate school because of the experimental work and nuclear physics involved with nuclear materials.

This is my second year with the DHS-STEM internship program and every year I learn a new set of valuable technological skills. The full time employees at the lab are constantly in a changing environment, always learning new skills and gaining knowledge in either their current department, or migrate easily to a new one. Departments hold seminars so the scientific community (students and employees) is knowledgeable of ongoing projects at the lab and employees with matching skill sets can transfer to a different project of interest. This internship experience has helped me figure my pathway for graduate school, how to get involved with emergency response, how to code in Python, and has increased my Matlab skills.